

# SUBSTITUTE SPECIFICATION



TITLE

## **PROPULSION DEVICE, FLYING OBJECT COMPRISING THE SAME AND PROPULSION DEVICE IGNITING METHOD**

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### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention generally relates to a propulsion device and igniting method thereof and more specifically to a propulsion device and  
10 igniting method thereof both excellent in response performance as required for attitude control of an artificial satellite, lunar probe, planet probe, on-trajectory work station, launch vehicle or other aerospace craft.

#### 2. Description of the Related Art

15 As a bi-propellant type propulsion device using liquid fuel and liquid oxidizer as propellant, a propulsion device which uses dinitrogen tetraoxide (hereinafter referred to as NTO) as an oxidizer and monomethylhydrazine (hereinafter referred to as MMH) as fuel is known. This bi-propellant type propulsion device is preferably used for attitude  
20 control or trajectory change of an artificial satellite, on-trajectory work station, lunar or planet probe, launch vehicle or other aerospace craft.

But NTO or MMH, being a highly toxic chemical species, requires a special consideration for safe handling and also has an environmental risk if it leaks out. Hence, studies for changing-over to a less toxic propellant  
25 are being carried out.

As a less toxic propellant or mono-propellant, hydrogen peroxide (hereinafter sometimes referred to as  $H_2O_2$ ) is known. Also, as an operating method of a propulsion device, as designated by reference numeral 50 in Figs. 5 and 6, that uses hydrogen peroxide as an oxidizer, a mono-propellant mode and bi-propellant mode are known.

Fig. 5 is a schematic cross sectional view showing the mono-propellant mode of the propulsion device 50.

In the mono-propellant mode, the operation is done such that an oxidizer 30, that is, hydrogen peroxide as a first propellant, is supplied from an oxidizer supply means 10. The hydrogen peroxide is decomposed through a catalyst 16 so that high temperature oxygen gas 34 and high temperature steam 36 are generated and then the high temperature oxygen gas 34 and high temperature steam 36, as they are, are jetted out of the propulsion device 50 to thereby obtain thrust. A propulsion device like the propulsion device 50 is also called a mono-propellant type thruster in this field of the industry.

Fig. 6 is a schematic cross sectional view showing the bi-propellant mode of the propulsion device 50.

In the bi-propellant mode, the operation is done such that the high temperature oxygen gas 34 and high temperature steam 36 both obtained by the mono-propellant mode are supplied with fuel 32 as a second propellant from a fuel supply means 12 so that the high temperature oxygen gas 34, high temperature steam 36 and fuel 32 are mixed together in a combustion chamber 14. Thus, by a reaction of the fuel 32 with the high temperature oxygen gas 34, a high temperature carbon dioxide 38

together with the high temperature steam 36 is obtained and this is also jetted out of the propulsion device 50 to thereby obtain a larger thrust or specific impulse ( $I_{sp}$ ). A propulsion device like the propulsion device 50 is also called a bi-propellant type thruster in the field. The bi-propellant type thruster is more preferably used than the mono-propellant type thruster in a case where a high specific impulse is needed and a large propellant tank is provided.

It is to be noted that the term "specific impulse" represents the thrust per unit weight of the propellant and that the term "propellant" is used to collectively mean the fuel and oxidizer.

By the way, the start itself of the propulsion device 50 cannot be done by the bi-propellant mode. For the operation of the propulsion device 50 by the bi-propellant mode, such steps are needed that, while a fuel supply valve 12V is closed, an oxidizer supply valve 10V is opened so that the start is done by the mono-propellant mode and, after the temperature and pressure in the combustion chamber 14 are sufficiently elevated so that a necessary condition of temperature and pressure for ignition is secured, the fuel supply valve 12V is opened to start jetting of the fuel 32 and the operation is thereby shifted to the bi-propellant mode. As the propulsion device 50 is first started by the mono-propellant mode and then the operation is shifted to the bi-propellant mode, there is caused a time difference of several seconds for the shift of the mode, although the time difference changes according to the type of device and condition of operation. For this reason, the bi-propellant mode is not always appropriately used, especially in a case where a high response performance

or responsiveness is required, such as in a propulsion device for attitude control of an artificial satellite or in a propulsion device for direction change of an aerospace craft.

Further, in such a system where the start is done by the  
5 mono-propellant mode and then the operation is shifted to the bi-propellant mode, various means are required for detecting temperature and pressure in the combustion chamber 14 or for deciding the time of the shift and this invites a weight increase or complicated structure.

Also, if a combination of hydrogen peroxide and pure fuel is used, it  
10 may lead to a less ignitable property as compared with the combination of NTO and MMH as the conventionally used toxic propellant. That is, while the combination of NTO and MMH has a hypergolicity or self-ignitability, the combination of hydrogen peroxide and pure fuel is weak in such a property. Thus, if this property is to be supplemented, it is necessary for  
15 the upstream hydrogen peroxide to pass through thick layers of catalyst to be decomposed to become a high temperature gas appropriate for ignition and the thick layers of catalyst used therefor invite a weight increase. For this reason also, the bi-propellant type propulsion device is expected to be light in weight just as the propulsion device using NTO and MMH.

20 While details of the mechanism of ignition are not made clear yet, it is widely known in the field that a mixture of hydrogen peroxide and organic fuel has an explosive nature.

It is to be noted that, as another method to enhance the response performance of a propulsion device, one is known in which a metallic  
25 compound, amine, etc. are added to fuel as an additive for enhancing the

ignition performance or a highly reactive azide, etc. are used as a main component of the fuel so that hypergolicity of the fuel together with hydrogen peroxide can be obtained (e.g., Document 1).

Patent Document 1: USP5932837 (Especially, ABSTRACT)

5           However, the propulsion device shown in the Patent Document 1 has shortcomings, such as a contamination of the surroundings of an aerospace craft due to toxicity of the exhaust gas and solid wastes contained in the exhaust gas, a blockage of a combustor or injector, etc. and the area for which the propulsion device is used is limited. Also, if an  
10   azide is used, handling thereof is difficult and the area of use is further limited.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a  
15   propulsion device using a safer propellant and yet having both a high  $I_{sp}$  and a high response performance. Also, it is an object of the present invention to provide an igniting method of the propulsion device using a safer propellant and having a high response performance.

In order to achieve the objects mentioned above, the present  
20   invention is characterized in a construction comprising a preheated surface area increasing means (i.e., preheated surface area increasing device) in a combustion chamber.

By employing this construction, a temperature environment in which hydrogen peroxide as an oxidizer easily reacts with fuel for ignition  
25   or a colliding and mixing environment in which the oxidizer easily collides

with the fuel and easily mixes with the fuel can be realized. More concretely, the oxidizer and fuel are simultaneously jetted toward the preheated surface area increasing means. By so doing, the oxidizer and fuel, while they are mixing with each other, are efficiently heated by the preheated surface area increasing means and, at the same time, the reaction is rapidly accelerated to effect an instantaneous ignition. It will be more effective, if the oxidizer and/or fuel, before they collide with the surface area increasing means, are atomized by an appropriate means and then they are brought into contact with the surface area increasing means.

10 While a detailed mechanism in which a mixture of oxidizer and fuel creates an explosive ignition on a high temperature surface member is not made clear yet, such a phenomenon is widely known in the field. Also, while  $H_2O_2$  as an oxidizer passes through catalyst layers positioned upstream of the combustion chamber, it is decomposed to thereby generate  $H_2O_2$  decomposed hot gas. The jetted fuel spreads on the surface area increasing means so that its surface area is increased and thereby the contact area of the  $H_2O_2$  decomposed hot gas also becomes larger and the instantaneous ignition occurs.

Herebelow, the propulsion device and igniting method thereof according to the present invention will be described in more detail.

A first aspect of the present invention is a propulsion device that comprises a preheating means (i.e., preheating device) provided in a combustion chamber, a liquid fuel supply means (i.e., liquid fuel supply device) opening toward the combustion chamber, a surface area increasing means (i.e., surface area increasing device) provided in the combustion

chamber and an oxidizer supply means (i.e., oxidizer supply device) opening toward the combustion chamber.  $H_2O_2$  and an organic matter (fuel), when they are mixed together, have an explosive nature, but their self-ignitability is small enough so that instantaneous ignition does not occur. But according to the propulsion device of the first aspect of the present invention, the  $H_2O_2$  and fuel, respectively, are supplied (jetted) toward substantially the same position on the surface area increasing means to thereby collide with each other, or the  $H_2O_2$  and fuel, as previously mixed together by an appropriate means, are supplied, or both of them, while they are being atomized and mixed together, are supplied, thereby resulting in an instantaneous ignition. Thus, with a bi-propellant type thruster using a less toxic propellant, there is obtained an effect that a response performance and compactness of the device substantially same as in the above mentioned bi-propellant type toxic propellant thruster can be realized.

A second aspect of the present invention is a propulsion device that is characterized by, in addition to the first aspect, at least one of an orientation to which the liquid fuel supply means opens and an orientation to which the oxidizer supply means opens includes a vector toward the surface area increasing means. According to this propulsion device, one or both of the liquid fuel and oxidizer are jetted toward the surface area increasing means. The propellant thereby collides with the surface area increasing means so that atomization and mixing of the propellant are accelerated and the contact surface area by which the fuel contacts with the oxidizer is increased. Thus, there is obtained an effect that an

instantaneous ignition can be created and a high response performance as a propulsion device can be realized.

A third aspect of the present invention is a propulsion device that is further characterized by, in addition to the first and second aspects, a  
5 preheating means, that supplies heat, connected to the surface area increasing means. According to this propulsion device, the surface area increasing means has not only its own surface area increasing function but also a preheating function. Thus, there is obtained an advantage of weight reduction.

10 A fourth aspect of the present invention is a propulsion device that is characterized by, in addition to the first to third aspects, the surface area increasing means being formed in a net shape, a laminated net shape in which a plurality of nets are laminated or a honeycomb shape. According to this propulsion device, the weight of the surface area increasing means  
15 can be reduced, thereby reducing the mass of the surface area increasing means. Hence, heat quantity required for the temperature elevation can be reduced and the preheating can be done quickly.

A fifth aspect of the present invention is a propulsion device that is characterized by, in addition to the first to fourth aspects, a chemical  
20 species of the surface area increasing means being any one or more selected from the group of silver, platinum, palladium, ruthenium and iridium. According to this propulsion device, the surface area increasing means has not only its own surface area increasing function but also a function as a catalyser or decomposition catalyst to decompose the  
25 hydrogen peroxide. Thus, a smooth ignitability and high response



performance can be realized.

Nothing of the present invention excludes the use of a metal, nickel for example, that is not mentioned in the above group as the chemical species of the surface area increasing means. But if a metal not mentioned in the above group is used, the possibility of an occurrence of a hard ignition becomes increasingly high. Hard ignition means an explosive ignition in which a large quantity of propellant instantaneously reacts due to ignition delay, and this is not preferable in view of the reliability of the parts and components. Hence, as the chemical species enumerated in this fifth aspect are all precious metals having a catalytic performance to decompose  $H_2O_2$ , the problem of hard ignition can be easily avoided. The mechanism of hard ignition and avoidance thereof will be described later. It is to be noted that, in cases where a requirement for the reliability of the parts and components is comparatively small, a heat resistant alloy of a comparatively low cost can be employed to thereby realize a cost reduction. As a heat resistant alloy of this kind, nickel alloy or niobium alloy is known.

Next, several modes of using one kind or more kinds of the precious metals will be described with reference to Figs. 4(a) to 4(d). Figs. 4(a) to 4(d), respectively, show cross-sections of wires forming a metal-made net or wire 18, as described later, as the surface area increasing means. In these respective figures, while cross-sections of a clod or solid form 20 of a first chemical species forming the wires, cross-sections of fine particles 26 of the first chemical species and cross-sections of fine particles 24 of a second chemical species are shown in circular shapes, it is a matter of course that

the cross-sections of these wires and particles of the present invention are not limited to the circular shapes.

As the mode using a plurality of the herein enumerated chemical species, there can be various forms of realization. Examples of the various forms of realization are as follows, a form having a portion of a surface of the clod 20 of the first chemical species covered with a plated layer 22 of the second chemical species, as shown in Fig. 4(a), a form having the surface of the clod 20 of the first chemical species supporting the fine particles 24 of the second chemical species, as shown in Fig. 4(b), a form having a net of the first chemical species and a net of the second chemical species alternately laminated on each other, and a form having a surface of a clod of a chemical species not enumerated herein supporting particles of the first chemical species and particles of the second chemical species. It is a matter of course that a mixture of the chemical species of three kinds or more can also be used.

Also, as a mode using only one kind of the chemical species enumerated herein, there can be employed a form having the entire surface of the clod 20 of the first chemical species covered with a plated layer 22 of the second chemical species, as shown in Fig. 4(c). More concretely, as the first chemical species, a kind of a comparatively low cost is employed among the above mentioned precious metals and as the second chemical species, a kind of a comparatively high cost is employed among the precious metals. Thus, apparently, the surface of the net 18 only of the second chemical species is exposed to be used. In this form, even if the plated layer of the second chemical species is peeled off, the surface of the

first chemical species is exposed in turn so that the same or similar effect as in the above mentioned forms using the plurality of chemical species can be continuously obtained. Thus, by the surface area increasing means constructed as mentioned above, an effect to reduce the quantity of use of the expensive precious metals can be realized. If large sized hardware is to be manufactured, a large cost reduction can be obtained, as well as an optimization of the activation of the catalyst surface condition. As a matter of course, such a form as having a surface of a clod of a chemical species not enumerated herein covered with a plated layer of the chemical species enumerated herein can also be employed. For example, in order to reduce the quantity of use of silver, a method in which a wire (net) of nickel alloy or stainless steel is applied with silver plating is known.

By applying plating of the first chemical species to the surface of the clod of the first or second chemical species, a minute roughness of the surface or an increase of the surface area can be realized. This can be done by optimally carrying out the control of the electric current density in the plating process. For example, in a silver net manufactured by wire materials, the surface is relatively flat. But it is known that, if the wire materials are previously applied with silver plating or the silver net is applied with silver plating, then the minute roughness of the surface can be increased.

Also, as a variation to use one kind of the chemical species, such a form as having the surface of the clod of the first chemical species supporting fine particles of the first chemical species, as shown in Fig. 4(d), can be employed. In the surface area increasing means so

constructed, as compared with the case of the clod only, the microscopic surface area per the macroscopic area is increased and an effect to enhance the reaction activation can be obtained. For example, a form having a surface of a clod of platinum supporting fine particles of platinum, that is, platinum black, can be utilized.

Also, as another variation, where a support is made of a substance that is inactive as a decomposition catalyst to decompose the hydrogen peroxide, for example a ceramic selected from the group of alumina, silica, silica gel, etc., a form having a surface of this support supporting fine particles of the first chemical species can be employed. The ceramic in this case may also be a more historic type of ceramic if such a ceramic is as excellent in strength and heat resistance as a ceramic called a fine ceramic in the field. Accordingly, reliability of the entire propulsion device can be enhanced.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic cross-sectional view showing a first embodiment of a propulsion device according to the present invention.

Fig. 2 is a schematic cross-sectional view showing a variation of the first embodiment of Fig. 1.

Fig. 3 is a schematic cross-sectional view showing a second embodiment of a propulsion device according to the present invention.

Fig. 4 comprises Fig. 4(a) to Fig. 4(d), wherein Figs. 4(a) to (d) respectively show cross-sections of wires that form a metal-made net provided in a propulsion device according to the present invention.

Fig. 5 is a schematic cross-sectional view showing a mono-propellant mode of a propulsion device as a related art.

Fig. 6 is a schematic cross-sectional view showing a bi-propellant mode of a propulsion device as a related art.

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#### DETAILED DESCRIPTION OF THE INVENTION

Herebelow, the present invention will be described in more detail based on embodiments of the invention and with reference to the appended drawings.

10 Fig. 1 is a schematic cross sectional view showing a first embodiment of a propulsion device 2 according to the present invention.

In Fig. 1, the propulsion device 2 is shown to jet exhaust gas in the right-hand direction so that the propulsion device 2 moves in the left-hand direction. A net or wire 18 made of a metal is provided in the propulsion  
15 device 2. An oxidizer 30, of which the flow rate is appropriately adjusted, is supplied from an oxidizer storing means (i.e., oxidizer storing device) (not shown) via an oxidizer supply valve 10V and is jetted into the propulsion device 2 by an oxidizer supply means 10 (i.e., oxidizer supply device). Likewise, fuel 32, of which the flow rate is appropriately adjusted, is  
20 supplied from a fuel storing means (i.e., fuel storing device) (not shown) via a fuel supply valve 12V and is jetted into the propulsion device 2 by a fuel supply means 12 (i.e., fuel supply device). Here, the oxidizer 30 and fuel 32, respectively, are jetted so that they are joined together preferably at one point on the net 18, that is, for example, at a central point of the net 18 as  
25 schematically shown in Fig. 1. For this purpose, both of the oxidizer

supply means 10 and fuel supply means 12 are opened at an angle relative to a wall surface of the propulsion device 2, that is, an angle of about 45 degrees in the example shown in Fig. 1.

In the present propulsion device 2, it is difficult to clearly define the scope of a combustion chamber 14. But the scope of the combustion chamber 14 is generally understood to be the portion of the net 18 and the downstream vicinity thereof. This is because it is taken into consideration that the point on the net 18 where the oxidizer 30 and fuel 32 are joined together is the starting point of the combustion and that the direction in which steam 36 and carbon dioxide 38 generated by the combustion can proceed, that is, the direction in which the combustion can spread, is the right-hand direction in Fig. 1.

The reason why the downstream side of the propulsion device 2 is formed in a constricted shape is to regulate the jetting of the steam 36 and carbon dioxide 38 as well as to regulate the direction thereof. But this does not directly relate to the object of the present invention and detailed description thereof is omitted.

As the oxidizer 30, liquid hydrogen peroxide is employed. Consistency of the hydrogen peroxide is not specifically limited, but if the consistency of the hydrogen peroxide is low, a predetermined thrust cannot be obtained unless a surplus of the oxidizer 30 is utilized. This surplus of the oxidizer 30 becomes a burden and is disadvantageous. That is, in order to obtain a high  $I_{sp}$ , a higher consistency is preferable. If this is considered, the consistency of the hydrogen peroxide is preferably 50% or more in weight, more preferably 80% or more in weight or most preferably

90% or more in weight, however, there is no upper limit in any case.

As the consistency of the hydrogen peroxide approaches to 100% in weight, a unit cost of the hydrogen peroxide increases. This high percentage of hydrogen peroxide may appear to be disadvantageous, but as  
5 the consistency becomes higher, the cost of loading the surplus of the propellant can be reduced and this can sufficiently make up for the disadvantage of increase of the unit cost of the hydrogen peroxide. As the loading of the surplus propellant requires loading of further surplus propellant for launching the propellant itself, the disadvantage is more and  
10 more magnified.

Especially, if the propulsion device is used for launching a space rocket, as the flying object is launched against gravity, even a small reduction of the weight can bring forth a large cost reduction as a whole. As a propellant used for launching a space rocket, even if hydrogen  
15 peroxide of 99.9% in weight, for example, is used, the consistency may not be excessively high.

There is no specific limit to the shape of the oxidizer supply means 10, and a cylindrical shape or gradually enlarged tube shape, for example, can be employed.

20 Also, as a variation of the first embodiment, if the oxidizer supply means 10 is positioned upstream of the net 18 to open orthogonally or at an angle toward the combustion chamber, a similar effect can be obtained. Fig. 2 is a schematic cross-sectional view showing a propulsion device 2 having such a construction.

25 It is to be noted that, in Fig. 2, the propulsion device jets the

exhaust gas from the left to the right and the left-hand side is the upstream side and the right-hand side the downstream side.

There is no specific limit to the kind of the fuel 32 and any one of alcoholic fuel represented by ethanol, ketonic fuel represented by acetone  
5 or methyl ethyl ketone, hydrocarbonic fuel represented by JP-8, JP-10 or kerosene, amine fuel represented by tetramethylethylenediamine or triethylamine, or a combination thereof can be used. JP-8 and JP-10 are names of aerofuel well known by experts in the field.

There is no specific limit to the shape of the fuel supply means 12  
10 and a cylindrical shape or gradually enlarged tube shape can be employed. The fuel supply means 12 opens at an angle toward the upstream side from the downstream side of the combustion chamber. There is no specific limit to the direction of the opening. But if it is considered that the fuel is to be mixed with  $H_2O_2$  or an instantaneous ignitability is to be  
15 obtained, preferably by simultaneously heating the fuel and  $H_2O_2$  on the net 18, it is basically preferable that the fuel and  $H_2O_2$ , respectively, are jetted toward a target at the same one point of the net 18. In the example of Fig. 1, the fuel is jetted from the right hand lower position and  $H_2O_2$  from the right hand upper position so that imaginary lines of the respective  
20 jetting directions cross together at one point on the net 18.

In the propulsion device 2 constructed as shown in Fig. 1, as the net 18 of a thin catalyst can be used in place of the thick catalyst 16 of Figs.  
5 and 6 that has been used in the propulsion device 50 of a related art, advantages of a compact size, light weight, low cost, etc. can be obtained.  
25 Also, the structure becomes simplified and the realibility is enhanced.



Moreover, as the mono-propellant mode itself can be eliminated in the propulsion device 2 constructed as shown in Fig. 1, such a propulsion device with an excellent start-up can be obtained.

5 The flow rate of the fuel 32 supplied from the fuel supply means 12 via the fuel supply valve 12V and that of the oxidizer 30 supplied from the oxidizer supply means 10 via the oxidizer supply valve 10V are different according to the kind of fuel or type of the propulsion device. However, the flow rate can be appropriately determined by experts in the field, thus a detailed description thereof will be omitted.

10 Further, in the propulsion device 2 shown in Fig. 1, there is connected a preheating means (i.e., preheating device) (not shown) for the net 18 so that the net 18 is supplied with heat. There is no specific limit to the type of preheating means (e.g., electric heating, infrared radiation, etc.,) to be employed. Extent of the preheating is preferably so that a  
15 sufficiently high temperature can be realized relative to the boiling point of the fuel 32. More concretely, in case the fuel is ethanol, an alcohol, or acetone, a ketone, the preheating is done preferably to a temperature of 100°C or more, and more preferably of 150°C or more.

But, if not necessarily higher than the boiling point of the fuel 32, if  
20 a temperature near the temperature of the boiling point is realized, an effect to enhance the combustion performance can be obtained. This is for the reason that, at the temperature near the boiling point, vapor pressure of the fuel 32 is elevated and thereby gasification of the fuel and  $H_2O_2$  is accelerated as well as reaction activation of the propellant is accelerated.

25 According to experiments using JP-10 that has a boiling point of

182°C, it is confirmed that an ignition is effected only by preheating the JP-10 to 150°C.

In the propulsion device 2 shown in Fig. 1, the material of the net 18 is silver. The net 18, made of silver, has a catalytic capability for reaction to decompose the hydrogen peroxide and the problem of hard ignition can be avoided. Material, other than silver, having such a catalytic capability is platinum, palladium, iridium, ruthenium, etc.

Detailed mechanism of the ignition or hard ignition is not made clear yet. But the presently known phenomena are described as follows. That is, if a metal that is weak in catalytic capability for reaction to decompose the hydrogen peroxide is used as the material of the net 18, an ignition delay becomes large so that a large amount of propellant is accumulated. Then, the reaction proceeds suddenly and a spike of pulse-like high pressure is generated, thereby inviting a risk of damaging the surrounding parts and devices. Such an ignition is called hard ignition by experts in the field. However, if the above mentioned precious metals having the catalytic capability are used as the material of the net 18, H<sub>2</sub>O<sub>2</sub> is first decomposed to be gasified and oxygen generated by the gasification makes contact with the fuel to thereby effect ignition. In this case, a mild ignition is realized as compared with the case where the liquid H<sub>2</sub>O<sub>2</sub> as it is makes contact with the fuel for ignition. Such an ignition is called mild ignition by experts in the field.

Another technical purpose for using precious metals having catalytic capability is as follows. That is, even if no ignition is effected, the object is to quickly decompose the H<sub>2</sub>O<sub>2</sub> component so that it is made

non-toxic when discharged outside. That is, the object is to obtain higher safety as compared with the case where undecomposed  $\text{H}_2\text{O}_2$  is discharged outside of the propulsion device.

There is no large difference in the catalytic action between the above enumerated precious metals. If a low cost is preferred, silver is preferably used. On the contrary, if durability is preferred, iridium or ruthenium can preferably be used. If a combination of obtainability and mild durability is preferred, platinum can be employed. Here, the durability relates to a problem of heat-resistance. That is, the problem is whether the catalyst can stand to be exposed to a combustion of a long time. If a high heat resistant metal is to be selected, a metal which has a high melting point can be selected. Here, the melting point of each of the precious metals is compared as follows: iridium ( $2446^\circ\text{C}$ ) > ruthenium ( $2250^\circ\text{C}$ ) > platinum ( $1768^\circ\text{C}$ ) > palladium ( $1555^\circ\text{C}$ ) > silver ( $962^\circ\text{C}$ ).

Also, there is no specific limit to the purity of the above enumerated precious metals. But it is preferable to use those of a high purity to the extent obtainable. This is because the weight increases from the existence of impurities. The fact that weight reduction is important in the field of the present invention is described above. As for the kind of metal that is easily obtainable, there is known platinum 900 on the market. This is an alloy containing platinum of 90 weight % and palladium of 10 weight %.

The preheating means connected to the net 18 for supplying heat can be provided in an arbitrary structure so that decomposition of the hydrogen peroxide can be accelerated.

(An example of experiments)

A test device is prepared for ignition tests in simulation of the material and shape of an ignition portion of a propulsion device. This test device is for confirmation not of a continuous combustion but of a start time of ignition and has no combustion chamber 14. The positional  
5 relation of the oxidizer supply means 10, fuel supply means 12 and net 18 is the same as shown in Fig. 1 and illustration thereof is omitted. Ethanol as the fuel 32 and  $H_2O_2$  as the oxidizer 30 are used and a surface area increasing means of net shape is employed to form the net 18. The net 18 is made of silver and is kept in a preheated state.

10 In the above mentioned condition, ignition tests were carried out and an ignition of 15 milliseconds after contact of the oxidizer with the fuel was confirmed. Measurement of the time was done by a high-speed camera. This ignition delay is near the one obtained in a propulsion device using a toxic propellant.

15 Fig. 3 is a schematic cross sectional view showing a second embodiment of a propulsion device according to the present invention.

The present second embodiment is different from the first embodiment of Fig. 1 in that the oxidizer 30, after it has passed through a catalyst 16, becomes  $H_2O_2$  decomposed hot gas to enter the combustion  
20 chamber. The term " $H_2O_2$  decomposed hot gas" is used to collectively mean oxygen 34 and steam 36 generated by the decomposition of  $H_2O_2$ . In the first embodiment, as soon as the oxygen 34 and steam 36 are generated by the decomposition of  $H_2O_2$ , they meet with the fuel 32, but in the second embodiment, the oxygen 34 and steam 36, generated by the  
25 decomposition of  $H_2O_2$  while it passes through the catalyst 16, meet with

the fuel 32 on the net 18. While there is a slight time delay until the  $H_2O_2$  decomposed hot gas meets with the fuel 32 in the second embodiment, the effect exhibited by both of the embodiments is the same in consequence.

Also, the point that the oxidizer 30 is jetted in parallel with the axial  
5 direction of the propulsion device 2 is different from the first embodiment. But the fact that the oxidizer 30 meets with the fuel 32 at one point on the net 18 is the same as in the first embodiment and the effect exhibited by both of the embodiments is also the same.

The present second embodiment is made such that the main point  
10 of the conventional  $H_2O_2$  bi-propellant type thruster is improved. In the conventional  $H_2O_2$  thruster, the fuel is directly jetted in the high temperature  $H_2O_2$  decomposed gas. While this method enables a stable ignition, as it is necessary to blow the fuel when the temperature and pressure of the decomposed gas are sufficiently elevated by the  
15 mono-propellant mode, there is a problem in that it takes time to shift to the bi-propellant mode, as mentioned before. Hence, this problem is improved in the present second embodiment. That is, the fuel is jetted onto the preheated surface area increasing means and thereby a portion of the fuel is gasified and the remaining fuel is also spread on the surface  
20 area increasing means. Thus, the contact surface area and contact time of the fuel with the decomposed gas generated by the decomposition of  $H_2O_2$  can be increased. With the propulsion device constructed as mentioned above, the ignitability can be enhanced and the response performance can also be enhanced.

25 Also, even in case that the requirement for the response

performance as a propulsion device is not very severe, the present second embodiment can exhibit an effect as follows, that is, as the result of the enhanced ignitability, the volume of the combustion chamber 14 necessary for the ignition reaction can be reduced and the weight of the combustion chamber 14 can also be reduced. This enables the propulsion device 2 itself to be made smaller and lighter. Here, if the propulsion device is started by the mono-propellant mode, the net 18 can be preheated by heat of the decomposed hot gas itself generated by the decomposition of the hydrogen peroxide and thereby a predetermined performance can be obtained even if no exclusive preheating means is provided.

The net 18, preferably the preheated metal net, of the second embodiment is arranged between the generated gas obtained by the decomposition of  $H_2O_2$  and the fuel 32. The gasification of the fuel 32 and the reaction activation of the fuel 32 with the generated gas can thereby be accelerated. It is to be noted that the effect obtained by the increase of the contact surface area is the same as in the first embodiment.

If necessary, a heating means can be provided between the oxidizer supply means 10 and combustion chamber 14. The decomposition of the hydrogen peroxide is thereby accelerated so as to realize a smooth ignition, and a high response performance as a propulsion device can be obtained.

In the second embodiment, while the mono-propellant mode cannot be eliminated, the necessary time for the mono-propellant mode can be reduced. In the second embodiment, the pressure and temperature conditions required for shifting to the bi-propellant mode from the mono-propellant mode can be mitigated as compared with the conventional

propulsion device. More concretely, even if the surrounding pressure or temperature is comparatively low, shifting to the bi-propellant mode can be done. The time to shift to the bi-propellant mode after the start of the mono-propellant mode can thereby be reduced. Also, the combustion  
5 chamber can be designed smaller.

The propulsion device of the present invention, as described above, has a high response performance and is made in a compact size, as compared with the conventional bi-propellant type thruster using  $H_2O_2$ . Also, with respect to any of the response performance, specific impulse,  
10 compactness and simplicity, the propulsion device of the present invention has a performance near to that of the conventional toxic propellant thruster using the combination of NTO and MMH, yet can avoid the difficulty of handling caused by the high toxicity of NTO and MMH.

Thus, the propulsion device of the present invention can be  
15 preferably applied to the attitude control of a flying object that requires a quick attitude control, such as an artificial satellite, on-trajectory working station, lunar probe, planet probe, guided aerospace craft, launching rocket, etc.

If the flying object is a guided aerospace craft or launching rocket, a  
20 main propulsion device can be separately provided for propulsion only and the propulsion device of the present invention can be used as a sub-propulsion device, that is, an exclusive attitude control device. The propulsion device exclusive for attitude control can exhibit its effect even with a small thrust. But in order to control the attitude in an arbitrary  
25 direction, it is preferable to provide a plurality of propulsion devices

exclusive for attitude control. The term "attitude control" as used herein includes control to correct or change the trajectory on which the flying object moves.

5 In every kind of flying object, it is a matter of course that the main propulsion device and sub-propulsion device can be provided by the propulsion device of the present invention. But, as a single propulsion device can hardly control the attitude, it is preferable that the flying object is provided with a plurality of the propulsion devices.

10 Also, if the flying object is of a type that moves on its trajectory without a propulsion drive force, and there is needed no main propulsion device, it can have only the propulsion device of the present invention. As such a flying object, an artificial satellite can be named, for example.

15 According to the present invention, a propulsion device using a non-toxic propellant and yet having both of a high thrust or specific impulse and a high response performance can be provided. Also, according to the present invention, a flying object excellent in attitude control performance can be provided.